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ENGIN STORAGE
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1921
no. 7
Engineering

CRUMPTON
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W. A. BOOTH
Secretary

P. P. REYNOLDS
Treasurer

# OFFICIAL PROCEEDINGS

Meeting of October, 1921

Volume XX
No. . . . 7

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OCTOBER
1913

# Canadian Railway Club

MONTREAL

PARVA SUB INGENTI

## CONTENTS

Report of October Meeting and paper and discussion

on

"Studies in Corrosion of Iron and Steel"

OF TORONTO

**TUCO PRODUCTS CORPORATION.**
Passenger Car Specialties—National Standard Roofing—Tuco Flexolithe Composition Flooring—Trap Doors "National" and "Universal"—Window Screens "Imperial" and "Universal"—Insulation "Tucork" and "Resisto."

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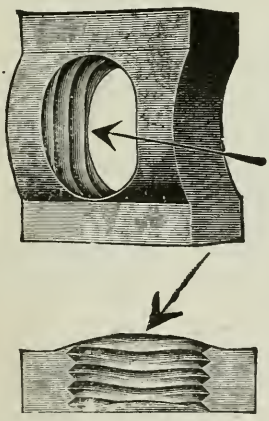

This cut shows an exaggerated curve in thread pitch.

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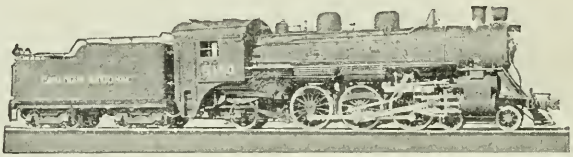

Total weight of engine, 260,000 pounds
Weight on drivers, 164,600 pounds
Diameter of drivers, 69 inches
Boiler pressure, 200 pounds
Cylinders, 23½ x 28 inches
Maximum tractive power, 38,100 pounds

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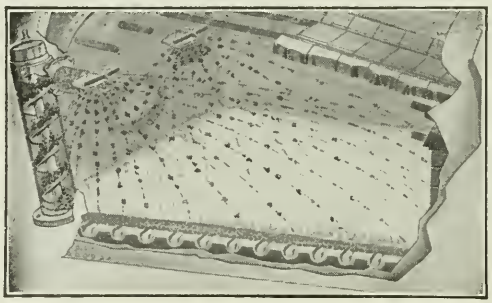

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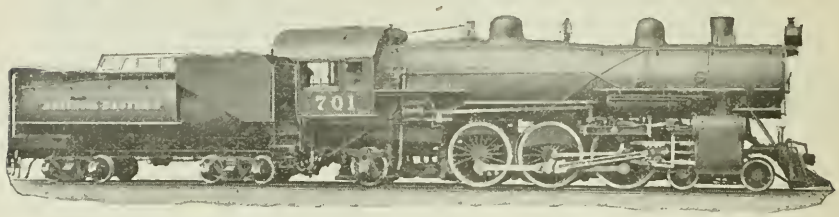


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W. A. BOOTH, Secretary, 53 Rushbrooke Street, Montreal.

Vol. XX. No. 7 **Montreal, Can., Oct. 11, 1921** 25c. per copy

# PROCEEDINGS OF THE CANADIAN RAILWAY CLUB

Windsor Hotel, Montreal.
October 11th, 1921.

Chairman (Mr. Arthur Crumpton):

Gentlemen, the usual attendance cards have been placed on the tables, and I will ask that everyone here sign one of these cards in order that we may have a record of those present. If you will kindly pass them along to the centre of the room they will be collected later on

MEMBERS PRESENT:

Crumpton, A.
Barrett, C. W.
Barry, G. M.
Barton, A.
Benger, F.
Bermingham, J. C.
Besse, R.
Black, R. D.
Black, R. H.
Boughton, L.
Branston, Wm.
Broaderip, M.
Brooks, P. A.
Brown, L.
Burns, Claude
Burns, W. J.
Burns, E. W.
Burns, John
Camp, W. J.
Cameron, G. R.
Campbell, A. J.
Campbell, N. M.
Coleman, J. W.
Coleman, Milton
Cookman, R. C.
David, C. H.
DeAngelis, H.
Diplock, H. J.
Eisile, O.
Farey, F. O.
Ferguson, F.
Ferguson, J. P.
Fielding, W. G.
Firth, M.
Frith, G. H.
Fyfe, J. E.
Gardner, K. U.
Gigg, T.
Goldstraw, W.
Graves, W. F.
Graves, Wm. M.
Groten, M. N.
Hazen, C.
Hamm, W. C.
Hanson, L. J.
Harold, J. G. D.
Harragin, H. C.
Hanison, J.
Hassall, C.
Henderson, J. A.
Hendry, John
Hersey, M. L.
Holland, N.
Horwood, A.
Horwood, H. E.
Hudson, T. C.
Hunter, W. C.
Hunter, Wm.
Inns, Geo. A.
Ivory, Wm. M.
James, H. H.
Job, Robt.
Johnson, H.
Jones, R.
Kenny, J. P.
Kinnear, D. M.
Lammers, W.
Lathrop, C. B.
Maase, B. A.
Mackie, R. L. D.
Masse, O.
Matheson, A. G.
Menard, J. P.
Mynard, T.
McAvoy, P. L.
McHattie, F. W.
Naylor, H. R.
Needham, R. J.
Palme, John E.
Paxton, J. D.
Peat, A. N.
Pepper, A. H.
Peverley, R. D.
Pierpoint, F. H.
Plant, E. B.
Pope, A.
Pope, J. G.
Powell, Jas.
Prouse, Wm.
Pugh, Geo. W.

Ramsay, W. E.
Richardson, A.
Richardson, A. C.
Robb, G. W.
Ross, J. D.
Scott, A. N.
Sharpe, H. W.
Spence, Wm.
Spence, W. A.
Stamford, A.
Stewart, T.
Stewart, W. H.
Summers, W. S.
Symmes, H. H.
Tate, W. F.
Theobold, E. G.
Thomas, E. W.
Thorburn, C. D.
Turner, F. C.
Vincent, G.
Whitcomb, F. E.
Whitcomb, F. O.
Wills, W.
Wilson, G. M.
Wilson, H. A.
Winship, R. B.
Yale, J. A.
Yost, W. H.
Booth, W. A.
and others.

Secretary:

The following applications have been received since our last meeting:

## NEW MEMBERS

A. W. Allyn, Manager Sales Dept., U.S. Steel Products, Montreal.
J. A. Altimas, A.G.S.C.S., Canadian Pacific Railway, Montreal.
N. M. Barclay, Asst. Engineer, Grand Trunk Railway, Montreal.
L. F. Beaudry, Canadian Pacific Railway, Montreal.
E. Baxter, Clerk, Canadian Pacific Railway, Montreal.
J. B. H. Benard, Errors & Claims Clerk, C.P.R. Telegraph, Montreal.
A. N. Boyd, Road Foreman, Grand Trunk Railway, Montreal.
W. L. Bayer, Canadian Bronze, Ltd., Montreal.
T. P. Brennan, Clerk, Canadian Pacific Railway, Montreal.
P. E. Brougham, Chief Clerk, W. & R.S. Dept., C.P.R., Montreal.
W. Bryson, Draftsman, Canadian Pacific Railway, Montreal.
G. A. Bulmer, Clerk, Car Service Dept., C.P.R., Montreal.
E. S. Collins, Chief Clerk, Canadian Pacific Railway, Montreal.
G. Cooke, Patent Attorney, c|o Wm. McFeat Co., Montreal.
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A. J. Fairclough, Chief Tracing Clerk, C.P.R., Montreal.
J. Forbes, Chief Clerk, Car Service Dept., C.P.R., Montreal.
G. H. Frith, Asst. Engineer, Grand Trunk Railway, Montreal.
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F. C. Knight, Asst. Engineer, G.T.R., Montreal.
V. P. Kojeski, Supt. Rld. Service, Dominion Oxygen Co., Montreal.
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H. Lebrecque, Clerk, Canadian Pacific Railway, Montreal.
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F. N. McAnulty, Salesman, Sam'l Osborn (Canada) Ltd., Montreal
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A. A. Mislap, Statistical Clerk, C.P.R., Montreal.
R. A. Norris, Rate Clerk, Grand Trunk Railway, Montreal.
A. O'Brien, Clerk, Canadian Pacific Railway, Montreal.
J. O.'Brien, Clerk, Canadian Pacific Railway, Montreal.
C. S. Ogilvie, Asst. Engineer, Grand Trunk Railway, Montreal.
A. J. Oliver, Clerk, Canadian Pacific Railway, Montreal.
A. N. Peat, Clerk, Canada Iron Foundries, Ltd., Montreal.
A. M. Perras, Branch Manager, Lackawanna McCrory Coal Co., Montreal.
W. Phelan, Car Acc't, Canadian Pacific Railway, Montreal.
L. E. Prevost, Clerk, Canadian Pacific Railway, Montreal.
J. N. Smeaton, Computer, Grand Trunk Railway, Montreal.
J. L. Smith, Clerk, Grand Trunk Railway, Montreal.
J. B. Starkey, Draftsman, Canadian Pacific Railway, Montreal.
J. H. Todd, Chief Dispatcher, Canadian Pacific Railway, London Ont.
J. B. Wain, Asst. Engineer, Grand Trunk Railway, Montreal.
H. P. Walsh, Chief Clerk, President's Office, G.T.R., Montreal.
J. Watson, Clerk, Canadian Pacific Railway, Montreal.
C. F. Weaver, Foreman, Grand Trunk Railway, Montreal.
P. W. Wheeler, Clerk, Canadian Pacific Railway, Montreal.
C. R. Williams, Eastern Representative, West Disinfecting Co., New York.

Chairman:

You have heard the list read over by the Secretary. These members have all been passed on by your executive and accepted.

During the week I was talking to someone about joining our club, or rather, some person was talking about it and said he had never been asked to join. I thought it is not very likely that anyone in the railway service will have this excuse, for in the September proceedings you will find special application forms, and it is trusted that each member will make use of these forms and bring in a new member by next month.

Chairman:

Tonight, we have the pleasure to have with us Dr. Allerton S. Cushman, Physical Director of the Institute of Industrial Research, Washington, D.C., and he is going to give us a paper as you see, entitled "Studies on Corrosion of Iron and Steel" (Developments of the past ten

years). I have asked Dr. Cushman if he will give us a few remarks on his experiences abroad, having just returned. I have pleasure in introducing Dr. Cushman.

Dr. A. S. Cushman:

Almost immediately on landing in America from quite an extended visit to England, Belgium and France, I was greeted with your kind invitation to appear before your Club. If any explanation or apology is necessary for what I am offering you tonight, it is that I had very little time at my disposal in order to get into your Secretary's hands a manuscript which would be in proper order for printing for your meeting and your proceedings.

Now, in regard to my visit to England, Belgium and France this past summer, I can only hope to touch some of the high spots. I found metallurgical industry in England almost dead, for the time being only we will hope. I was told that there probably was not a blast furnace in operation in the United Kingdom. This was due primarily to the coal strike. The price of coal was so high that it was impossible to contemplate the manufacture of pig iron, and since pig iron is of course basic to the whole steel industry, this practically meant that pig iron had to be imported into England, perhaps from the recent enemy country, if there was to be any steel making carried on. As a matter of fact, as long as the present exchange situation continues to exist in its present condition, I do not see how Great Britain can compete in any world-wide sense with a nation that can pay its labor in marks worth less than a cent apiece and export finished material to sell around the world, collecting on the dollar or pound sterling basis. In France, the conditions are more interesting. The British Iron and Steel Institute, of which I am a member, held their annual meeting this year in France. After the stated meeting and the reading of a few technical papers, they split up into groups for excursions. One group went to Alsace-Lorraine and another, which I elected to join, went to the great Snyder plant at Creusot, in the south-central part of France. We were very hospitably greeted, and nothing was omitted to make our visit pleasant. Every opportunity, I think, was given us to see all that the French are doing at that great and wonderful plant. I hope that the courtesy on the part of the French manufacturers will be reflected by the English-speaking steel manufacturers through their organizations. I have already written a letter as a member of the

American Iron & Steel Institute, suggesting that the British Iron & Steel Institute be invited to hold one of their annual meetings in the near future in conjunction with the American Iron & Steel Institute. This seems an impracticable suggestion on first thought on account of the high cost of crossing the Atlantic and of hotels and transportation in the States and in Canada. However, I think that the industries of the American continent, as well as individuals who can afford it, would be only too glad to subscribe to an entertainment fund which would reduce at least the expense account of the visit of foreign metallurgists to our shores to that point to which it would not be considered as prohibitive. My own feeling is, that many of the misunderstandings that certainly exist today as much as ever they did, between the different Nationals, is due to the fact that they have never mingled with or visited each other, have never reached out to try to grasp each other's ideals. Since the steel industries are basic to civilization, to the arts of peace as well as to the arts of war, I believe that if we could get the men who control the business destinies of the great steel manufactories to visit each other in each others countries, some, at least, of the misunderstandings in our basic industries would tend to disappear. Now to go back for a few moments to the Creusot plant. When I was asked my opinion of it shortly after my visit when the impression was fresh in my mind, I replied that, if they have such things as steel plants in heaven, they must be very like the Schneider plant at Creusot. I had not dreamed that a steel plant could be surrounded by such an environment nor enjoy such beautiful natural conditions.. The plants are located in the midst of vineyard-clad hills in the richest part of Bergundy. There is little or no smoke, no grime, nor none of the filthy or degrading conditions that so often grow up around our industrial centres in America.

Everything possible is done for the working people. Their cottages are models.

Operating normally, the plant, I believe, employs about fifteen thousand hands. I was told they were now operating with about seven thousand. Of these, a considerably large percentage, I don't just know how large, not more than 30 per cent, I should think, were Chinamen, presumably left in France and demobilized after the war. There were a great many women in the plant doing work I am accustomed to see only men who have shown that they are

capable of occupying responsible positions, given to do in this country. Women were operating 10-ton cranes that were moving big machinery and products about the plant. Women also worked as moulders along with the men in the foundries. I suppose that the employment of so many women as I saw and so many Chinamen, was due to a shortage of man power left over in France after the War and certainly did not seem to betoken unemployment in France which is bothering us all so much in all English-speaking countries. The plant was also most astonishing to me for another reason. It was principally occupied in manufacturing a number of finished locomotives of the powerful Pacific type. I think these locomotives were principally for the French Government, for use in the African possessions. I was told that nearly everything that goes into a finished locomotive is manufactured in the plant. That is rather unusual because in this country locomotive manufacturers would not have sheet mills, blooming mills and all the various kinds of equipment that have to be employed to make all the separate parts that go into a finished locomotive.

In addition to locomotives, they were making very large canon, the largest I have seen. I have been an Ordnance Officer, but I never have seen such large land service guns as the French are manufacturing today. When I asked what they were for—of course a shrug of the shoulder, but we knew perfectly well they were intended to point across the Rhine. The fact is that every Frenchman, from President to office boy, believes they are not through with the German menace yet and that if they are left alone to live under this sword of Damocles without help from the Allies, that disarmament cannot be considered by them.

During my visit I had an opportunity of comparing notes with many colleagues from England and other countries who are interested in corrosion problems. I presume the reason you extended an invitation to me to address you on this subject is because you find that the corrision of iron and steel is a problem that comes into your daily experience as engineers and that you cannot avoid being interested in the subject.

I will then with your permission proceed with the reading of this paper which I have prepared.

In 1910 the writer published, in co-authorship with Mr. H. A. Gardner, a rather compendious volume on "The Cor-

rosion and Preservation of Iron and Steel.'' In the preparation of this work, the authors attempted to set forth not only everything that was known to date on this important subject,but also new theories and explanations of corrosion phenomena were developed and demonstrated. In fact, it may be fairly stated that in 1910 the electrolytic theory, or better, the electrolytic explanation of the corrosion of metals, first made its apearance and challenged the attention and criticism of the metallurgical world. This theory on the whole has stood the test, and is now commonly accepted by those best qualified to form judgments, as at least furnishing a rational working explanation of a varied and wide range of phenomena. Briefly stated, the electrolytic explanation of corrosion boils down to this: No metal can corrode or rust unless it first enters into solution in water or some watery solution or liquid medium. Having entered into solution, the atoms ionize and obey the laws of electrolytic dissociation. To put it in very practical language, it may be stated that iron cannot corrode or rust unless water is present to act as a medium and unless also oxygen is present to complete the oxidation of the resulting ions. Those of you who have at least a bowing acquaintance with physical chemistry, know that on entering into watery solution, the molecules of which all material substances are made up, dissociate into constituent atoms or groups of atoms which carry equal and opposite charges of static electricity. Such charged atoms are known as ions and as in the case of water taken as an example would be written H and OH. The corrosion of iron, the subject which immediately concerns us at this time, is nothing more nor less than an electrical phenomenon. There is abundant evidence to prove the truth of this statement,as all may learn who take the time and trouble to study the abundant literature of the subject. Ten years ago all this sort of scientific explanation and discussion was in much the same condition as a cut-up puzzle in which the very numerous jig-saw pieces were being tediously and gradually fitted into their proper places, but the picture as awhole was far from finished and was as yet not recognizable as an ordered or purposed fact. Some pieces would not seem to fit in anywhere, and others seemed to have been jammed in anyhow, whether they fitted or not. At the present time the picture is still far from complete, but the advance of scientific knowledge in what has come to be known as the ''higher physics'' seems to be making pieces fit in where only blank spaces have been hitherto discernable. I am referring now to the knowledge that has been gained of the act-

ual constitution and configuration of the material atoms. We now know with very considerable certainty that an atom of matter is a sort of solar system in miniature, inasmuch as that it consists of a central electropositive nucleus around which are grouped electronegative satellites moving with orbital precision with reference to their nuclei and to each other. Under certain circumstances, however, these electrons are detachable from one system and attach themselves to neighbouring ones with the result that the one system becomes electropositive by depletion of electronegative electrons, while the other becomes electronegative by carrying for the time being a surplus of electrons. The simplest illustration that I can think of is the experiment made thousands of years ago, that eventually gave electricity its name from the yellow fossil gum amber washed up on the shores of the bleak and stormy Baltic Sea. If a piece of amber be rubbed with a cloth, it will not only pick up a bit of paper or pith or other light non-metallic substance, but the substance will actually jump across a slight gap to meet the amber as it approaches. Here was action at a distance, even if only a small distance,and such gigantic intellects as Isaac Newton and many another before and after him could make nothing of it. It now appears that many substances are composed of atoms in which the attendant electrons are only lightly held, and that they can actually be wiped off and joined up temporarily with neighbouring systems. Thus we leave one body electropositive by the abstraction while the other becomes electronegative by the addition of electrons. Now, by analogy, when a surface of iron is brought into contact with a watery medium, the solution pressure of the atoms on the contact surface forces some of them to migrate, but they leave electrons behind on the parent surface, so that the iron ion in solution for an appreciable instant appears as a positively charged ion or atom devoid of its full complement of electrons. This, however, is an unstable state of affairs and the wandering oxygen molecules in the solution, in conjunction with the ever present negative hydroxyl ions (OH) become actively engaged in carrying electrons to the iron ions to make up the deficit. In the meantime, however, the negatively charged metallic surface has an excess of electrons which we might permit ourselves to say it has no use for. These electrons will move away in the direction of any atom that is deficient in electrons—in other words, to any electropositive spot or area. Electrolysis is then at work and corrosion and pitting proceed apace. If the action is going

on in a corroding medium in which the atomic or molecular aggregates formed by the rushing together of the positive iron ions and the negative hydroxyl ions are insoluble, the hydroxides will build and accumulate upon the corroding surfaces as colloidal rust. It is difficult to understand all this unless we call upon our imaginations to follow the restless migration of electrons from one atomic system to another as the change of energies takes place. It even helps if we will permit ourselves to think of the electrons as living cells striving to get away from unstable and uncomfortable environments and to attach themselves to groups in which they can quietly settle down and revolve in peace and quiet. But between the solution pressure on one side attempting to make the atoms leave home and the osmotic pressure of the free ions in the watery medium trying to kick them back again, they have a restless time of it. About as restless on their plane of magnitudes as a football in a big game, which does not stay put in any one position very long but finds itself the plaything of contending forces continually pushing it in opposing directions. If, however, there is no oxygen present in the watery corroding medium.corrosion does not go on. * Iron atoms will tend to go into solution but are pulled back by the electron they leave behind, so that they do not succeed in migrating, and the surface becomes, as we say, polarized. It is only when the oxygen brings about precipitation of the iron ions as hydroxides that the way is cleared for more to come crowding in, so that the corrosive action becomes progressive. I find it helpful to think of the contact surface between the metal and the corroding medium as a sort of space-lattice or grating through which the atoms have to squeeze or crowd to get into solution, incidentally wiping off and leaving behind some of their electrons in transit, and then immediately the push and pull of the opposing forces are exerted through the bars. This may seem a somewhat fanciful presentation, but to my mind it expresses something very like what actually does take place.

* *This fact, which was pointed out in my papers as early as* 1907 (*see "Corrosion and Preservation of Iron and Steel," Cushman and Gardner, McGraw-Hill Book Co., N. Y., p.* 42 *et seq.*) , *is now put to commercial and practical use in deactivating water in boiler pipe line and heating systems, as see a very full report on the whole subject in the French periodical, Chimie et Industrie for July,* 1921, *Vol.* 6, *No.* 1, *p.* 11 *et seq.*

I have, at all events, accomplished part of my present purposes if I have stimulated your minds to consider the corrosion of iron and steel from the standpoint of the electronic constitution of matter, in other words, as being a purely electric phenomenon. As I have pointed out, the picture is still incomplete, but the scientific knowledge which has been attained as a result of the discovery and study of radium and its congeners, is helping us to fit pieces into the puzzle, that find the appropriate vacant places waiting for them.

Now, it must be apparent that if a metallic surface subject to corrosive attack has an unequal solution pressure at different points on its surface, due to segregation of impurities or unequal stresses and strains, or for any other contributory reason, the negative electrification of the surface will be unequal and unstable, so that the electrons are kept in an extraordinary state of movement and surging backward and forward, seeking equilibrium. Corrosion in such a system is continually being stimulated, for at no time is any stability reached. The ideal condition would be when the solution pressure was a minimum and exactly constant for every atom making up the surface. Unfortunately ideal conditions are never quite reached in any form of human endeavour, but it is practical and possible to approximate an ideal and to hope to progress nearer and nearer to one's goal as time goes on. It was with these thoughts in mind that in 1905, as a government official at that time I began to urge American steel makers to attempt the manufacture of commercial pure iron in the open hearth furnace. It was claimed by practical metallurgists that such an attempt would merely spell disaster, that the higher temperatures and time required in running down carbon and manganese to traces would be destructive to furnace and ladle linings, while the bath would be superoxidized and worthless. In fact, the experiment had already been tried by the eminent metallurgist, H. H. Campbell, and had failed, while all the compendious treatises on iron and steel metallurgy, including that of Ledebur, the famous German, stated the impossibility of using the open hearth furnaces in any such way. My own attitude was that while admitting the metallurgical difficulties, the only thing worth doing today is the thing most people say can't be done. Although the suggestions made by me at the time were free for all, the challenge was accepted only by one steel manufacturing plant. After many costly metallurgical adventures, this company solved the problem, and as they achieved the so called metallurgical impossible by de-

monstrably novel use of the furnace, it was quite proper and good business ethics to seek the protection that the patent laws of all civilized countries extend to invention.

It is needless for me to review here the great success that has followed the introduction of pure open hearth iron all around the world, but as the manufacture of commercial pure iron, 99.84 p.c. actual iron, on the large tonnage scale usual in steel manufacture represents an important contribution to corrosion resistant products of the past ten years, it is pertinent to our present subject.

It was, of course, impossible that such an important metallurgical development should go unchallenged and that some alloy should not be sought, that would give the same added resistance to corrosion as pure iron attained in comparison with ordinary steels. As a matter of fact, a very great number of alloys and metallurgical combinations have been made and tested by a great number of investigators, with this end in view,but so far only the so called copper-steel, which is ordinarily a mild steel containing about 0.20 percent of copper has come under discussion and also into prominent use as a corrosion resistant metal. I am not appearing before you here in order to praise the qualities of any one type of metal or to criticize the claims made for another. Although it is well known, and I suppose understood by your body in general, that I am a protagonist of purity when all around corrosion resistance is the special object sought, nevertheless I claim the right to approach the subject as a scientific investigator of many years standing in corrosion problems.

Now, the tests conducted by the American Society for Testing Materials on bare, uncoated corrugated sheets in the sulfurous atmosphere of Pittsburg, Pa., seem to have shown that in tests made under just those conditions, copper has exerted a restraining action on the progress of atmospheric corrosion. On the other hand, tests conducted by the American Society for Testing Materials by immersing blanks cut from the selfsame Pittsburg sheets, when immersed in mine water indicate that the effect of copper was either ineffective or positively deleterious. Now, these latter results check up with the results of many hundreds of tests conducted in the laboratory and in service by the writer and his colleagues. In a recent paper * I dealt with this subject as

*"*Anomalies Encountered in a Study of Immersion Tests of Iron and Steel," by Allerton S. Cushman and George W. Coggeshall. . .Presented before the Amer. Electrochem. Soc., Atlantic City, N. J., April* 21-23, 1921.

follows:

"From the results of the Pittsburg atmospheric tests of uncoated sheet metals, it may be inferred in a general way, in spite of some glaring exceptions, that the presence of a little copper as an alloying constituent lowers the solution pressure of the surface of the test piece, and thereby confers some measure of protection. The evidence on this point is confined, however, only to bare metal sheets exposed in an acid-bearing atmosphere, as is pointed out by Prof. O. Bauer of Berlin as the result of four year exposure tests, under many different conditions of exposure in Germany. **

"It is obvious to any unbiased mind that the conditions of an atmospheric test cover only a special set of conditions, which are not comparable to most of the conditions of service. Sheet metal is rarely if ever exposed to the weather in an uncoated condition. If the metal is not galvanized, it is at least painted, and when a coating is applied, the solution pressure at all points on the surface is no longer a factor in corrosion resistance Furthermore in other situations and conditions, th reactions of attack may change from acid to neutral or alkaline, or we may have to deal with partial or total immersion in the attacking medium. It is a fair question whether the alloying of small quantities of copper with steel under very many of these varying conditions is not actually deleterious and whether the conclusions that many people are drawing from the results of the American Society for Testing Materials, as well as other atmospheric tests. are not actually misleading. It is a fair question also, which has not yet been satisfactorily answered, as to just how copper as a constituent of iron or steel holds back the solution pressure of iron under exposure to an acid-bearing atmosphere. If the copper goes into solution proportionately as the iron ions pass in, and then tends to plate back again, it might under the circumstances retard or slow down the attack.

"The more slowly a rust-coating forms over the surface of a steel exposed to the atmosphere the more fine-grained, dark-colored, and tightly-adherent it appears, and undoubtedly under the conditions of such a test this is beneficial. If, however, copper passes into solution and then tends to plate back, it certainly would in part find itself able to do

** *Unfortunately, Bauer did not include test pieces quite free from copper but contented himself with studying a range of varying copper content down to* 0.09 *percent. A. S. C.*

so if the liquid phase which is an essential part of any corrosion system was sufficiently abundant and not too strongly acid, which it may not be in a bare weather test, where at no time is there present more than a very thin film of moisture. If in some other system copper does plate out, it should from the electrochemical viewpoint be very deleterious to the surface under attack."

Immersion tests made by the British Institution of Civil Engineers in sea water indicated that copper was not a desirable constituent in steel for marine constructions, and these results are in conformance with those obtained by the author not only in sea water but in many other solutions, notably solutions of various sulfates. Now, it is quite possible and even probable that a metallic constitution that is well adapted to withstand corrosion under one set of conditions may be quite unsuited to another. In fact, the records of numerous tests made by numbers of different investigators appear to all point more or less to this conclusion. If this is so, controversies on the subject remind us of the mortal combat between two knights of olden time over the color of a shield which was gold on one side and silver on the other, and which each observed from his own viewpoint only. An atmospheric test of bare steel is a film test only, for at no time is there more than a thin film of moisture or water present in contact with the surface. The migrations of the ions are necessarily very much restricted, for in fact, only two dimensional movement is possible, and the whole electrochemical equilibrium is quite different from that which would exist if the same sheet was fashioned into a tank or pipe and filled with water or a watery solution. Also the conditions are vastly different when the iron or steel surface is galvanized, and in every such case the less copper that is present in the system the better. If we place a clean piece of copper steel in a solution of a mercury salt, say mercuric chloride, we will find in time that a mercury mirror has formed on the steel but that this does not happen when copper-free steel or iron is used. Since mercury does not amalgamate iron but does copper, it is quite apparent that copper atoms have plated on the surface. Also if copper steel is pickled in an acid bath, after a time the equilibrium is such that copper plates back on the steel from the bath, and if galvanizing is then carried out on the pickled steel, the free copper atoms must alloy with the zinc. I believe it to be for this reason that the galvanized coatings on copper steel are usually much more rapidly attacked by salty solutions (electrolytes) than

the coatings in very low copper steel or iron. Since anyone can so easily make experiments of this kind,it is not necessary at this time to marshall evidence in support of these statements. Those who are interested are referred to the author's recent paper already cited.

What bearing all this may have on the practical questions that arise in engineering practice, you will not need to ask me. Ihave found a twenty percent solution of aluminum sulfate a convenient reagent to use in studying the resistivity of galvanized coatings to corrosive attack. Since nothing is needed with this test soultion except a few glass tumblers and some clean samples, an engineer can easily make his own observations without laboratory facilities. We may conclude that copper as an alloying constituent of steel is beneficial if our purpose is to put bare steel out in atmospheric exposure We are certainly not justified, however, in concluding that an atmospheric test is a good test, for the conditions of service generally dealt with, for all the available data point the other way.* It is noteworthy that although copper steel has become a regular article of commerce in sheet form, it is not offered or recommended, as far as I am aware, for wire, either black or galvanized, or for welded pipe or tubes, or for tank or boiler plates, and yet these constructions have to meet very corrosive conditions indeed.

I am attempting to treat my subject here in a scientific rather than a controversial spirit, although I cannot avoid the fact that my opinion and that of many investigators who agree with me is quite at variance with many others who have accepted the results of atmospheric tests as furnishing a criterion ofcorrosion resistance under all conditions of service. The proponents of copper steel have advanced the tentative theory that the presence of copper in some way overcomes the deleterious effect of sulphur in the composition of steel. I have examined this theory with all the microscopic and analytical facilities of the laboratory, and I can find no scintilla of evidence to support such an assumption. My own explanation has been set forth in the preceding pages. I believe that when copper is present as an alloying consti-

* *This point is confirmed in an interesting manner by Dr. J. Newton Friend, in his investigations on the protection of iron with paint. Friend has shown that precisely opposite effects were obtained in immersion tests from those obtained in atmospreric exposures. See Jour. British Iron and Steel Inst., Vol. CIII. No.* 367 (1921).

tuent, it tends to project its atoms or ions into solution along with the iron ions; if there is sufficient watery medium or liquid phase present the ions are free to migrate and, obeying their electrochemical equilibrium, plate out to a greater or less degree and more or less unevenly on the corroding surface. Such action is deleterious and promotes corrosion. On the other hand, under film conditions met with in atmospheric tests, the ions are not free to migrate.and action is stopped at the contact boundary. In this case the tendency of copper ions to hold back or plate back slows down the initial attack, permitting the copper bearing sheets to grain themselves with a tight, hard rust coating which acts as a partial protective coating against the subsequent attacks of the weather. I earnestly believe that if copper is beneficial in weather exposure of bare metal, it is actually deleterious under the great majority of all service exposures, and I have tried to set forth my reasons for holding to this opinion which I believe the future experience of engineers will fully confirm. I wish to follow the example of the illustrious Abraham Lincoln who once said in effect, I hold to my reasoned opinions very firmly but if the experience of the future shows me to be in the wrong, I shall modify my opinions in accordance with the facts.

Those of us metallurgists who do not believe in the introduction into steel of copper as an alloying constituent, must deplore its growing use. The author has already expressed himself on this subject as follows: *

"Quite aside from the scientific questions involved in these discussions, and differences of interpretations and opinion, there is involved a certain responsibility to the general metallurgy of the future. Our present, and in all probability to an increasing degree our future,steel-making processes must be in line with conservation of our national resources. In other words, our furnaces must use scrap as well as pig iron and ore. Copper is not eliminatable in iron and steel smelting, so that if copper-bearing specifications are to become general, there will be an inevitable tendency, with shrinking ore supplies, toward unavoidable high copper content in all commercial ferrous metals. If in the long run copper is proved to be deleterious for any considerable number of uses of iron and steel, our metallurgical descendants may well have reason to curse the era when fads were made a substitute for facts."

*loc. cit.

Chairman:

Gentlemen, the paper is in your hands for discussion. I am quite sure Dr. Cushman will be glad to answer questions put to him along the line of the paper.

Mr. R. D. Black.

As a representative of The American Rolling Mill Co., the only manufacturer of pure Iron today, I should like to make a few remarks.

Dr. Cushman refers on page 23 to some of the dificulties encountered in the manufacture of pure Iron. The principal difficulty, without enumerating a lot of them, is that of temperature. I do not think it is generally understood that pure Iron is worked in the furnace at a much higher temperature than mild Steel. We work it at about 300 deg. F. higher than mild Steel; this means that the bath may become oxidized or even superoxidized, as the Doctor mentions here. It is exceedingly hard on the lining of the furnace. Likewise, it takes about 25 per cent longer to get out a heat of pure Iron than it does of mild Steel, which we also make. This only increases our operating costs.

I should also like to say, in connection with Copper, that it is probably not generally known that we experimented a number of years ago with the addition of Copper to pure Iron. We added Copper in varying percentages all the way from .03 per cent to 3 per cent, which is the maximum amount of Copper which Iron will hold in solid solution. Larger amounts of Copper will precipitate out. We rolled this material into sheets but we did not find that Copper Bearing Sheets had any advantage over the pure Iron. We find from very elaborate and extended tests which we are and have been conducting that the pure Iron always has the advantage over the alloy for all round service conditions.

All of our experiments have only confirmed our original faith in purity and homogeneity as being the best insurance for uniformity and durability.

We have had ARMCO Ingot Iron in service in all parts of the world and under all conditions—not for one or two years, but for 12 years, and we now know from very carefully kept records, that it outlives ordinary steel of the same grade and gauge and under similar conditions, from 3 to 5 times.

As stated by Dr. Cushman, ARMCO Ingot Iron is 99.84 per cent pure Iron. We guarantee that in this way: that the impurities, namely,—Sulphur, Phosphorus, Carbon, Manganese, Copper, Silicon and the gases, Oxygen, Hydrogen and

Nitrogen, when taken in the aggregate, will not exceed 16-100ths of 1 per cent. As a matter of fact, from 1914 up to and including 1920, the average Iron content of all the Ingot Iron we produced during that period was 99.865 per cent.

Mr. W. E. Ramsay: (Vice-President, The Pedlar People Limited).

I wish primarily to express my appreciation of the paper that has been read by Dr. Cushman, whom I have known only by reputation for the past fifteen or sixteen years. Representing as I do a firm who are probably the largest users of sheet iron and steel in the Dominion of Canada, I might say that we have been vitally interested in the use and sale of pure iron and its products since about 1909. We have fabricated and sold pure iron and I think the North-American construction records bear it out. I will not name any particular brand or Mill, but having sold to the Canadian Railways and Manufacturers, tens-of-thousands of tons of pure iron products in the form of culverts, flumes, vents, smokejacks, eavetroughs, roofing, siding, etc., and having been carefully observant of the life and durability in all that time, we find it the most satisfactory material that has come under our observation for the past thirty-five years. We have never handled anything in our business life that gave us better satisfaction, or had less come-backs, than the materials that we have manufactured out of 99.84 or better pure iron.

Thank you.

Chairman:

I see Doctor Hersey here; we should like to have a word from him.

Dr. Milton Hersey:

Mr. President, it is certainly a great pleasure to me, as it must be to you and the rest of the Club who are here, to greet to-night Doctor Cushman with whose name we have been so familiar for a great many years, especially we who are interested in the various Railroads and Corporations and have to do with the testing of metals and so many other materials. Those who are in touch with iron and steel are of course familiar with the Doctor's reputation and his contributions to scientific literature. I am sure that I cannot add anything to what Dr. Cushman has said, but throughout the 32 years of experience I have had as a Chemist, having something to do with metals, and in touch with the maintenance of way men on the railroads, I have observed very frequently the rapid corrosion of certain kinds of iron, wire fencing for example, and have made analyses of various kinds of wire

used in fencing, and it is a most interesting study to see an attempt to correlate the reasons for the comparatively rapid failure of wire fencing. Those who have to do with railroads know what a large bill of expense wire-fence failures amount to per annum, particularly when one realizes the many thousands of miles of that kind of fencing used on each side of the right-of-way of the railroads in Canada; not to side of the right-of-way of the railroads in Canada; not to speak of farming-fencing,etc. Then there is the case of the corrosion of iron and steel which is "immersed" in water, like boiler tubes. These tubes frequently corrode because of the air held in solution, and give a great deal of trouble, and if something could be used to treat the water to remove that air before it got into the boiler and had a chance to do its dreadful corrosive work, it would be a very valuable thing for railwaymen.

I am intensely interested in all that the paper contains and all that has been stated by Dr. Cushman. We, of course, have heard a great deal about copper-iron and about "pure" iron. I wonder if perhaps copper-iron or copper-steel might be used for purposes where the metal is exposed to the atmosphere, and the "pure" iron, so fully described by Dr. Cushman, be used under other conditions, as for instance, where immersed in water, and especially for galvanized culverts, etc.

I wish to thank Dr. Cushman on my behalf to-night for the opportunity, as well as for the pleasure of hearing his address on this fascinating subject.

Mr. E. B. Tilt:

It has been some time since I have been interested in the subject of corrosion, which always must be a leading topic with anyone connected with railway work. I must echo what has been previously said in that I think the club is very fortunate in having such a paper put before it. There is no end to what might be learned about corrosion. It seems to me, however, that the exponents of pure iron are having it rather their own way. I unfortunately am not familiar with the recent development that has taken place in the use of copper. In confirmation of what Dr. Cushman has said I believe that at the Chateau Frontenac in Quebec after a great many trials of hot water piping of wrought iron which is not pure iron by any means, but which is different in some ways from so-called impure mild steel, they finally overcame trouble with corrosion by using water passed through a box filled with either steel or iron cuttings, and are now free from the troubles with which they were previously beset. Unortunately it is

a matter of 5 or 6 years since I have been following this at all closely and for that reason cannot add anything to the subject that is worth considering, but I believe there must be some here who can speak for the copper side and I should like to hear what they have to say on recent research.

Mr. Robert Job:

Dr. Cushman's talk tonight has been most interesting and instructive and gives us an insight into some of the corrosion theories with the development of which he has played a leading part.

These theories have changed decidedly within comparatively few years and it is much easier to-day to determine the real cause of corrosion in a given instance than was the case a short time ago.

Practical examples are always interesting and I will mention one which came to my attention not long since.

A boiler flue which had been in service in a marine boiler for only about three weeks failed, and on examination it was found that the steel at one end had been perforated either completely or very deeply in a number of places at a certain location on the flue. The remainder of the flue was in excellent condition and as serviceable as when first installed. Analysis in both locations showed that the steel was of good normal even composition which did not in any way account for the failure.

The design of the boiler was next investigated and it was found that the corrosion occurred at a place close to the intake. At times the level of the water in the heater became low and under these conditions air was pumped directly into the boiler and against the part of the flue which was corroded. Air, of course, contains oxygen and the latter, as is well known, is an active promoter of corrosion, and the pitting of the portion exposed to these conditions was fully accounted for. To stop the pitting it was necessary merely to trap the air so that it would not enter the boiler.

The corrosion of brass condenser tubes in marine service has been the cause of great inconvenience and expense. The subject has been very carefully studied by an English Commission and we should be interested to have Dr. Cushman state the latest results of the inquiry.

Still another instance of the ravages caused by corrosion is found in Winnipeg and the West and consists in the eating away of cast iron water-pipes by the alkaline waters.

Illustrations could be added almost indefinitely, all of them proving the immense money loss caused by corrosion under

many different conditions. To combat and put a stop to these difficulties one must have in mind clearly the causes of corrosion, or in other words, must know the theory, and I am sure that we all want to thank Dr. Cushman for the practical information which he has given in his paper to-night as well as for the help obtained from his previous work.

Dr. Cushman:

In regard to the corrosion of brass condenser tubes. That is a very important subject and there has been a good deal published on the subject, reference to which I have in my files, but I gather, although I have not specialized on that study, it has been found that wherever these brass condenser tubes fail they have invariably lost the zinc into the solution, in other words, that the zinc ions have passed into the solution faster than the copper ions. The explanation as to why it happens in certain sets of tubes and not in all brass condenser tubes, is the important question. We do know that whenever it happens, it is a question of bleeding of the zinc out of the brass and leaving the copper behind, that the action is electrolytic in the same sense that the corrosion of iron is electrolytic. I do not think there is any question about that. I think the general trend of opinion amongst engineers who have studied this problem, and I certainly agree with this opinion, is that the unusual corrosion is due to a condition of strain in the tubes. Brass that is improperly annealed can perform in very extraordinary ways.

Chairman:

As you all know, this is the Centennary of McGiill University, otherwise we would have had more McGill men with us tonight. I think there are some here and we would like to hear from them.

Dr. Stansfield: (McGill University).

I do not wish to add anything to what we have heard this evening with regard to the corrosion of metals and alloys, but I should like to say how much I appreciate the paper that has been read by Dr. Cushman. The subject of corrosion is one of very great interest and importance, but it is very complicated and many hours may be spent in reading the voluminous reports of investigating committees without arriving at a clear idea of the general nature of corrosion or the methods available for preventing it. It is very satisfactory therefore to be able to learn at first hand the conclusions that have been arrived at by a recognized authority in this field. With regard to the condition of Metallurgical industry in England, I was in Sheffield early in August and found

the iron and steel industry nearly at a standstill but I was informed that a number of blast furnaces were shortly to be blown in, which would lead to a general resumption of operations. I should like to learn what Dr. Cushman can tell us with regard to the present situation.

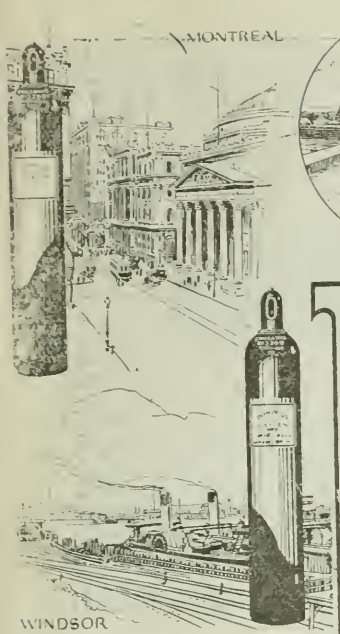
Dr. Cushman:

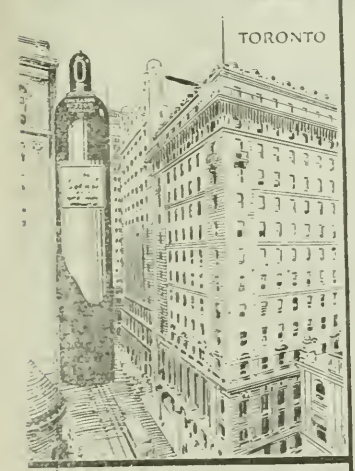
I left England the last week in August with the British Iron and Steel Institute for their meeting in Paris on September 5th, and when I left England I was told that things looked a little bit more cheerful and that some few blast furnaces in the Midlands were reported to be going into blast again.

Chairman:

Gentlemen, I am very loath to bring this meeting to a close, but we have to as the time is so far advanced. I am going to dispense with a formal vote of thanks and shall take the liberty of conveying to Dr. Cushman our appreciation of his lecture tonight.

Our next meeting on November 8th is going to be on Railroad Electrification and I think you will have a very interesting meeting. This I understand from the Secretary will be illustrated by Steropticon views. We have some refreshments and want to have time for these, and you will find them on the left as you go out.



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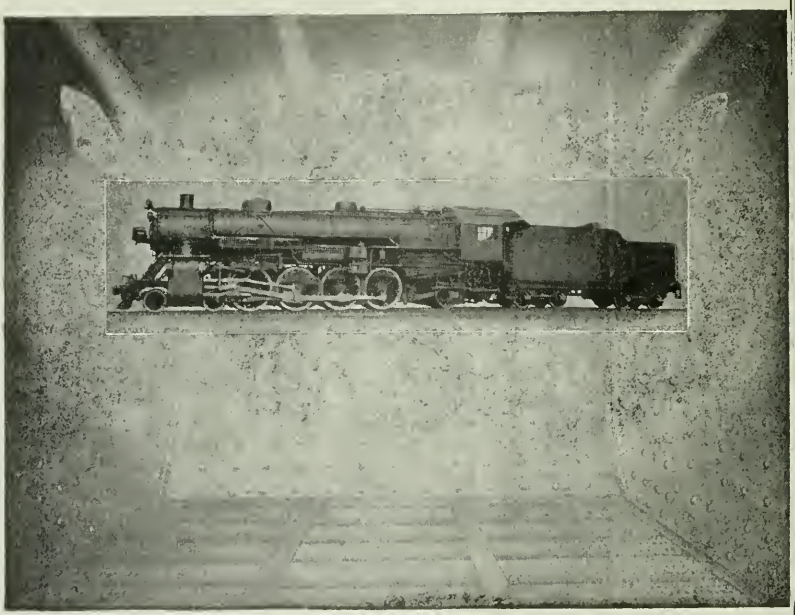

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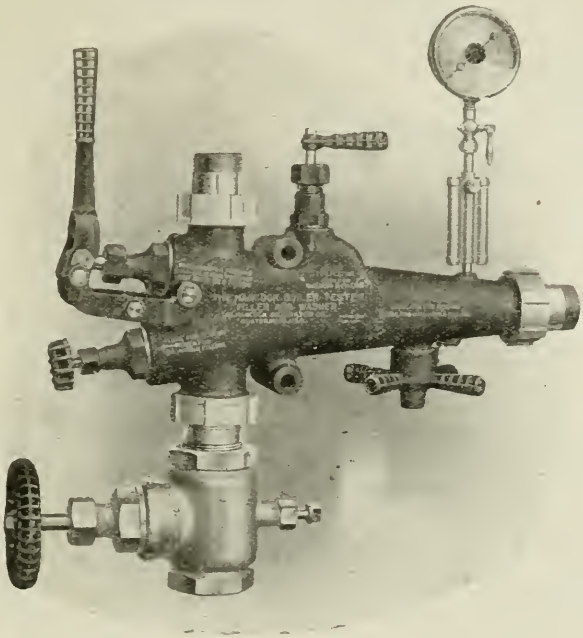

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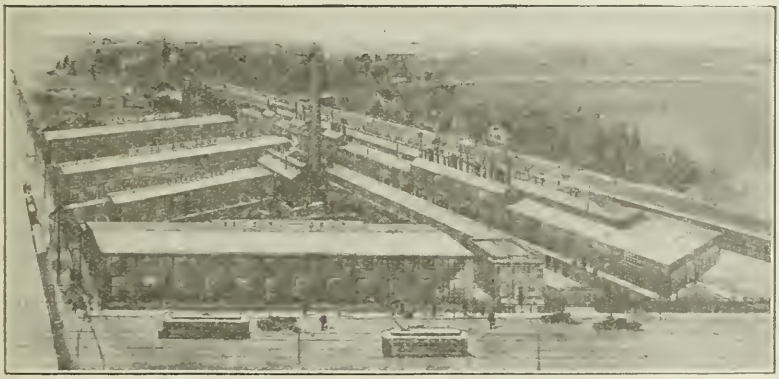

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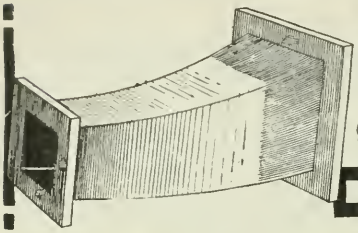

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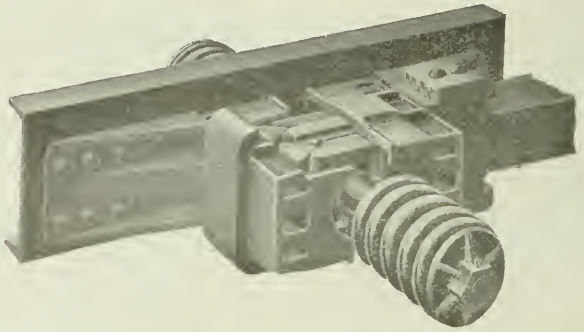

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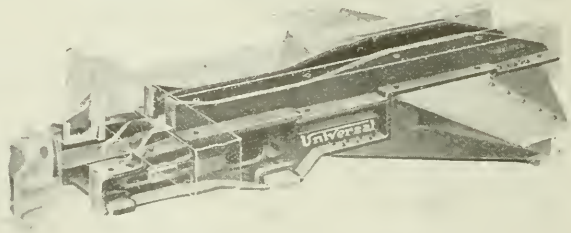


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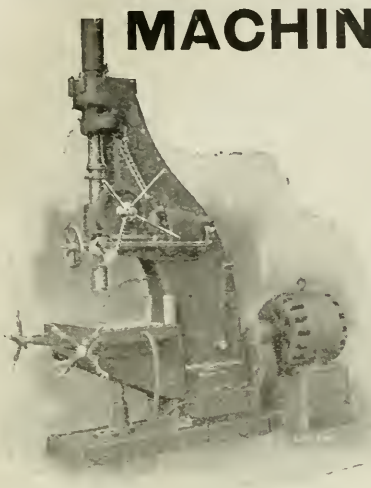

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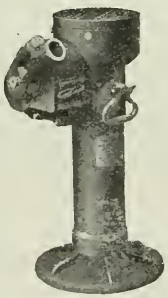

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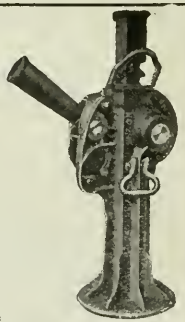

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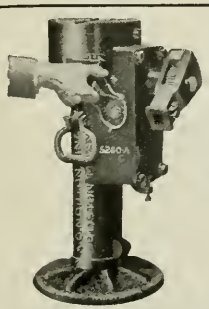

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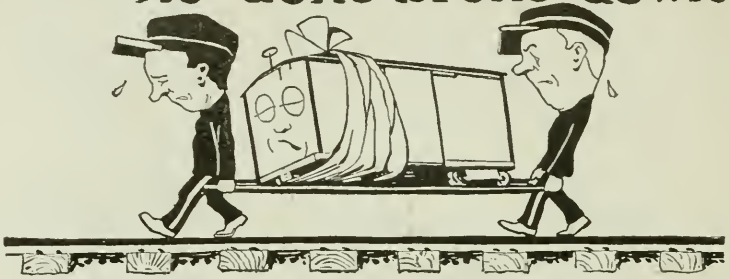

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